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Intercept Feeding as a Means of Reducing Deer-vehicle Collisions

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INTERCEPT FEEDING AS A MEANS OF REDUCING DEER-VEHICLE COLLISIONS

by

Peggy Wood

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of

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ABSTRACT

Intercept Feeding as a Means of Reducing

Deer-vehicle Collisions

by

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Intercept feeding was tested for its efficacy in reducing deer-vehicle collision frequency by diverting deer movement patterns away from highways using alfalfa hay as an attractant. Ratios of roadkills in control vs. treatment zones of three highway segments indicated that feeding reduced collision frequency. Spotlighting counts of live deer were significantly higher ($P<0.001$) in the control than in the treatment zone, supporting the effectiveness of feeding in keeping deer distant from the highway. In a benefit:cost analysis, the benefits accrued by reducing collision frequency exceeded the costs of feeding on each highway both years, with one exception: in 1986 one of the highways demonstrated that particular features of an area may not be conducive to effectively attracting deer away from a highway. I recommend intercept feeding be used with alternate techniques, so that the most appropriate technique is applied in each situation to reduce collision risk.

(45 pages)

INTRODUCTION

Collisions between deer (Odocoileus spp.) and vehicles are an important cause of highway accidents, resulting in substantial economic losses due to vehicle damage, loss of a wildlife resource, and human injury or fatality. Pils and Martin (1979), in Wisconsin, and Reed et al. (1982), in Colorado, estimated the 1978 average cost for vehicle damage at $500; Hansen (1983), in Michigan, estimated vehicle damage costs at $569 for the same year. From 1977 to 1984, vehicle damage from 108 collisions on a 48 km segment of SR 395 in eastern Washington totaled $82,000, an average of $760 per collision (Schafer and Penland 1985).

Collisions destroy countless deer. A review of records prior to the 1970's until the present illustrates a trend of increasing numbers of roadkill deer. Annual highway mortalities of deer have reached 21,242 in Michigan (Hansen and Wolfe 1983), 20,000 in New York (NSC 1984), and 32,325 in Pennsylvania (Penn. Game Comm. 1985). Nationwide, an estimated 200,000 deer-vehicle collisions occur each year (Williamson 1980). Records do not account for many fatally wounded deer.

Although injuries to motorists are uncommon and deaths are rare in deer-vehicle accidents, they do occur. From 1972 through 1976, Michigan State Police summarized 63,184 collisions involving deer (Arnold 1979). In 1.6% of the accidents the vehicle turned over; in 4.1%, the vehicle went on to hit a fixed object such as a telephone pole, culvert, or bridge; 3,289 motorists were injured, 17 killed (Arnold 1979). Hansen (1983) found that 4% of collisions in Michigan were reported as injurious. The National Safety Council (1978) reported that 100 people die in deer-vehicle collisions each year.

Various methods have been applied to reduce the risk of deer-vehicle collisions. Warning signs constitute perhaps the most common attempt to reduce collision frequency. However, research has shown "Deer Crossing" signs to be ineffective because drivers habituate to, then disregard, them (Williams 1964). Well-maintained fences at least 2.4 m high and constructed in long segments have proven most effective as a deterrent to deer (Reed et al. 1982; Ludwig and Bremicker 1983; Feldhammer et al. 1986). However, deer will penetrate flaws in this barrier.

A current and somewhat controversial method employs reflectors alongside the highway, the popular model being the Swareflex reflector. As the headlights of passing vehicles create a reflected red beam off each successive reflector, deer are exposed to an "optical warning fence" alerting them of danger (Strieter Corp., pers. comm.). Tests to evaluate their effectiveness have produced differing results. Studies have indicated effectiveness (Rudelstorfer and Schwab 1975; Gladfelter 1980; Williamson 1980; Schafer and Penland 1985) more often than ineffectiveness (Woodard et al. 1973; Gilbert 1982). However, whether deer have color vision at night and also whether deer will eventually become desensitized to this "optical warning fence" are questions that remain unanswered.

From 1978 to 1984, the Manitoba Department of Natural Resources (MDNR) averted deer damage to private hay stocks by providing food supplements on Wildlife Management Areas (Goulden 1985). In 1982, MDNR successfully applied this technique to highway segments with high deer-vehicle accident rates to reduce the frequency of collisions. This was the only investigation on the use of intercept feeding for the reduction of deer-vehicle collisions prior to the present study.

MDNR's program succeeded because the deer were provided a food more attractive than the forage for which the deer were crossing the road. The study indicated that deer movement patterns can be manipulated by providing a preferred food attractant (Goulden 1985). Seasonal migration patterns of mule deer (*O. hemionus*) involve movement between high-elevation summer ranges and lower-elevation winter ranges, often along traditional routes (Wallmo 1981). Both mule deer and white-tailed deer (*O. virginianus*) move daily between bedding and feeding grounds. Highways that intersect either form of deer movement pattern impose a high risk of collision on both motorists and deer.

In Utah, as in other northern-mountain states, deer-human interactions occur most frequently while deer occupy wintering ranges. As human development encroaches further onto deer winter range, negative interactions will continue to increase. Collision records for Utah show an increasing trend for the last 16 years (UDWR 1979, 1986). High collision frequencies in areas where highways intersect daily or seasonal deer movements might be alleviated if a food attractant diverted deer movement away from the highway.

This study, conducted during the winter months of 1985 and 1986, tested the efficacy of intercept feeding to divert deer movement away from highways and thereby reduce the frequency of deer-vehicle collisions in high risk areas. On three Utah highway segments with past records of high collision frequencies, I provided food as a diversion for deer in a treatment section while a comparable, but no-feed, section served as a control. The ratio of roadkills within the control zone and within the treatment zone of each highway indicated the effectiveness of feeding.

Study areas

The first highway segment was located on US Highway 89 (hereafter Hwy. 89) along the Wasatch Front in East Box Elder County, extending from the Brigham City intersection with US 91, south 20.8 km (13 mi) to Pleasent View. The deer population in this area summers in the Wasatch Mountains, then migrates west to the foothills to winter. Human development has encroached upon much deer winter range. Hwy. 89 bisects deer movement patterns as deer

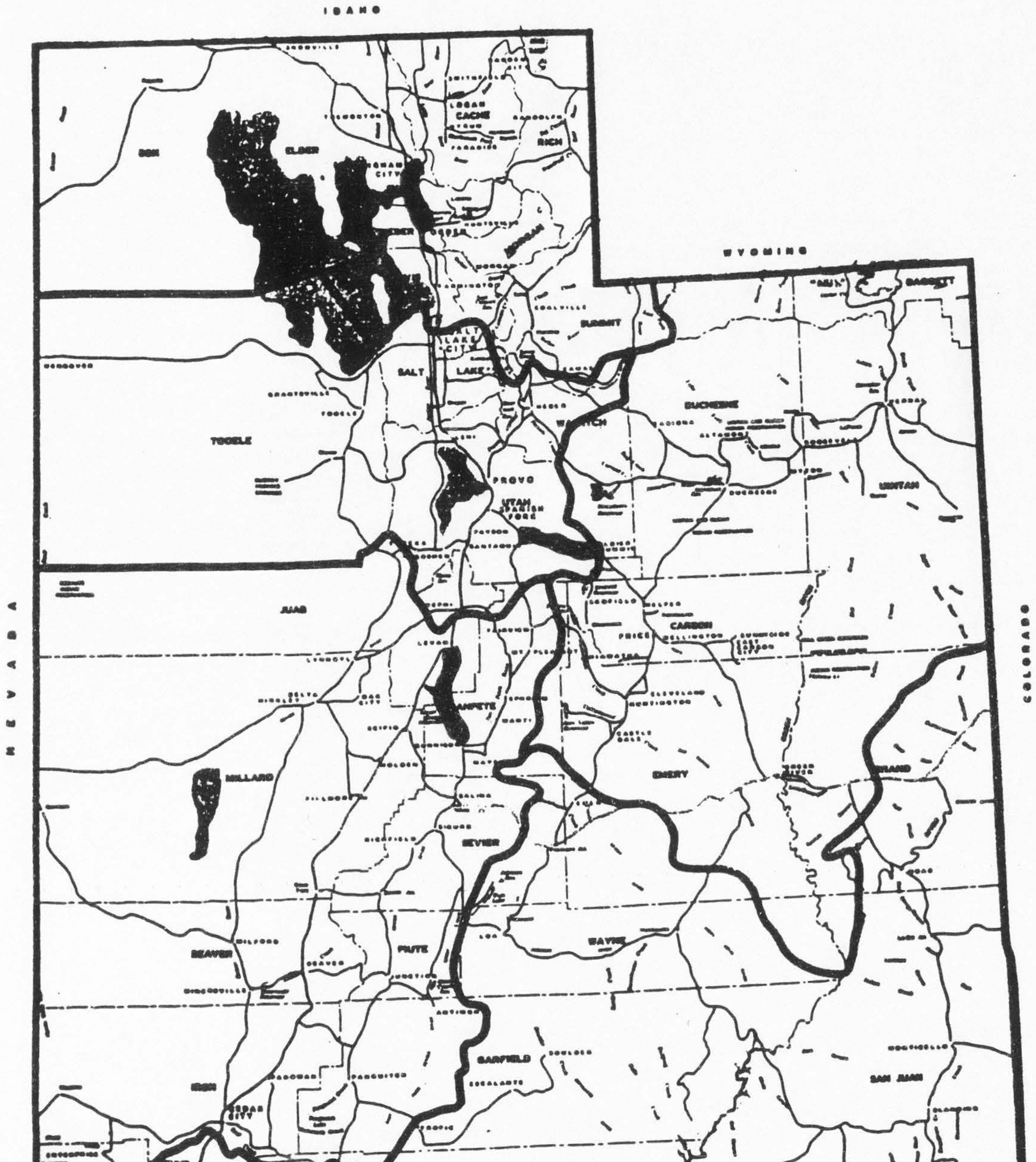

Figure 1. Study sites in Utah.

descend from the upper sections of the foothills, attracted primarily by apple and cherry orchards located on both sides of the highway. Among the three highways, human population density and traffic volume were highest here.

The second highway segment was located on US Highway 6 east of Spanish Fork Canyon in Utah County, beginning 0.8 km east of Thistle Junction and extending 24 km (15 mi) east to Tucker. This segment of Hwy. 6 winds through the canyon; topography ranges from steep canyon walls to rolling hills. Deer numbers in this area were considerably lower than in the two other study areas. Abundant elk posed an additional danger to motorists. Traffic was moderate.

The third highway segment was most suited for the implementation of this study. It was located on Utah Highway 28 adjacent to the western foothills of the San Pitch Mountains in Juab County, from milepost (MP) 28, 24 km south to MP 13. The area comprised primarily agricultural fields and pasture land. Topography ranges from flat areas to steep hills. Deer numbers in this area were highest of the three highways. Hwy. 28 intersected daily deer movements between the foothills and fields.

METHODS

The study segments on Hwys. 28 and 6 were divided into three zones of length 9.6, 4.8, 9.6 km (6, 3, and 6 mi); the zones on Hwy. 89 were 8.4, 4.2, 8.4 km (5.2, 2.6, 5.2 mi). These constituted feed, buffer, and no-feed zones, respectively. The buffer zone remained unmanipulated and served to divert any influence of the treatment (feeding sites) from the control zone. One of the two equal length zones was assigned as treatment in the first year, and then was interchanged with the control zone the second year.

Within both feed and no-feed zones, four sites were chosen for feeding stations. They were selected because they possessed topographic features conducive to funnelling deer movement to the stations, usually a canyon mouth, and were spaced as evenly as possible. The feeding sites on Hwy. 89 were located along a canal access road parallel to the highway and 1.2 km to the east. On Hwys. 28 and 6, a dirt road provided access to each site. The feeding sites along Hwy. 28 averaged 0.8 km from the highway, while those along Hwy. 6, 0.4 km.

Feeding began on January 2 of 1985 and 1986 and continued through mid-March. Provisions consisted of alfalfa hay, balanced-ration deer pellets, and apple mash. Apple mash served to attract deer to the sites. Pellets provided a nutritional supplement, but were distributed on a limited basis. Alfalfa hay constituted the main food supply. Salt blocks were distributed at the feed sites in

1985. I fed 2 out of every 3 days on Hwy. 28 and 1 out of 3 days on Hwy. 6. On Hwy. 89, the sites were replenished on a daily basis, as needed. Hay was supplied in quantities determined by the number of deer using the site and their apparent rate of consumption.

To evaluate the effect of feeding sites on deer highway mortality, the location (to the tenth of a mile), sex, age, and date of all roadkill deer on Hwys. 28 and 89 were recorded. Roadkills on Hwy. 6 were recorded by zone only.

Recorded roadkills represented total counts for each study area, with the exception of Hwy. 89 in 1985 when local officers removed an unknown number of roadkills. Analysis of the total counts were based on one assumption: disappearences of fatally wounded deer from a highway prior to my counts were uniformly distributed along the experimental segment and did not bias the ratio of roadkills in control to treatment zones. I reasoned there was no variance in the counts; accordingly, no statistical tests were applied.

Spotlighting counts of live deer within 270 m of Hwy. 28 provided support for the effectiveness of feed sites in keeping deer distant from the highway. Hwy. 28 afforded suitable characteristics including visibility of deer from the highway at night, open areas, paucity of residences, and safety by virtue of the highway's shoulder and straightness.

Counts were made with a 250-W, handheld spotlight. Starting at the north end of Hwy. 28, a driver maintained 40 km/hr while the researcher swept a 90° arc of light across the west side of the highway as the vehicle travelled south. As deer were sighted by body or eyeshine on the west side, their location to the nearest tenth of a mile and group size were recorded. The researcher spotlighted the east side while heading north from the southern end of the segment immediately following the west side count.

Detection of deer was sometimes restricted by land features. Accordingly, the percent of area obscured beyond 50 m was estimated during day and night periods by recording locations and lengths of land features which prevented observations. The direct spotlighting counts were then adjusted according to the locations and lengths of the obstructions and compared with the direct counts. Analysis of the data from the direct counts was accomplished using Fisher's Exact t-test and Spearman's Rank Correlation coefficient.

Browse utilization

I estimated browse use to evaluate the impact that deer concentrations had on the vegetation near the feed sites. Deer browse less preferred plant species only when more preferred species are not available or are too energetically expensive to access. It follows that concentrations of deer would use preferred species first, then less preferred species. Thus, deer utilization of less preferred species may be a more sensitive indicator of browsing intensity. Sampling focused on less preferred species.

Two of the four feeding sites in each treatment and control zone were chosen on Hwys. 28 and 6. At each feed site, three 200 m transects were established which radiated from the center at compass bearings 0^{o} (north), 120^{o}, and 240^{o}, respectively. Plot one, the central point on each site, was sampled. Plots at intervals 100 m and 180 m from the center were also sampled.

For each sample plot, I chose one plant of the browse species nearest the plot center. Species selection followed an order that was inversely related to deer preference (see Doman and Rasmussen 1944), namely: sticky rabbitbrush (Chrysothamnus nauseosus), big sagebrush (Artemisia tridentata), Mormon tea (Ephedra nevadensis), mountain mahogany (Cercocarpus montanus), bitterbrush (Purshia tridentata), and Stansbury's cliffrose (Cowania stansburiana). If rabbitbrush did not occur in the plot, sagebrush was selected, and so forth.

Two researchers estimated percent browse utilization on each plant after termination of feeding in 1985. They used ratios of (1) number of browsed twigs to the total number of twigs; and (2) mean length of twig browsed to the mean total length of twig. A composite average combined these indices. After the completion of feeding the second year, percent utilization was estimated on the same plants. Utilization estimates for treatment and control sites for Hwys. 28 and 6, and for 1985 and 1986 were tested for significant differences using a factorial split-plot analysis of variance.

Cost-benefit analysis

Intercept feeding must be cost-effective to be considered useful. State Farm and Allstate Insurance Companies provided damage claim amounts paid to clients with vehicles involved in collisions with deer during 1985 and 1986. These data provided a basis for the calculation of an average damage cost. Damages currently awarded to the state of Utah for the illegal taking of a deer provided a value estimate for a deer. Costs incurred by implementing intercept feeding included the purchase of foodstuffs, travel costs, and person-days of labor. Total costs were compared to estimated benefits realized by reducing deer-vehicle collision frequency.

RESULTS

Roadkills

Roadkills counted on Hwys. 28 and 89 indicated that intercept feeding reduced collision frequencies both years, whereas the counts on Hwy. 6 did not indicate effectiveness in 1986 (Table 1). Expressed as a ratio of roadkills that occurred in control vs. treatment zones, the ratios in 1985 on Hwys. 28, 89 and 6 were 1.63:1, 1.53:1 and 1.75:1, respectively; in 1986 the ratios were 2.34:1, 1.74:1 and 0.42:1, respectively. The occurrence of roadkills per mile on Hwys. 28 and 89 are illustrated in Figures 2-5.

Table 1. Roadkill totals for each highway per year and the percent of roadkills within control and treatment zones relative to the sum of the two.

Highway	Control (C)	Buffer	Trt. (T)	Total	C:T
Utah 28					
1985	31	13	19	63	1.63:1
1986	89	41	38	168	2.34:1
US 89					
1985	29	12	19	60	1.53:1
1986	59	21	34	114	1.74:1
US 6					
1985	14	5	8	27	1.75:1
1986	13	8*	31	52	0.42:1

*An additional 2 elk were killed here.

Temporal and spatial distributions of roadkills were examined more closely on Rts. 28 and 89 (Figures 6-9). Various factors affected when and where deer were hit, primarily by influencing deer movement patterns. Weather and topographical features influenced deer movement.

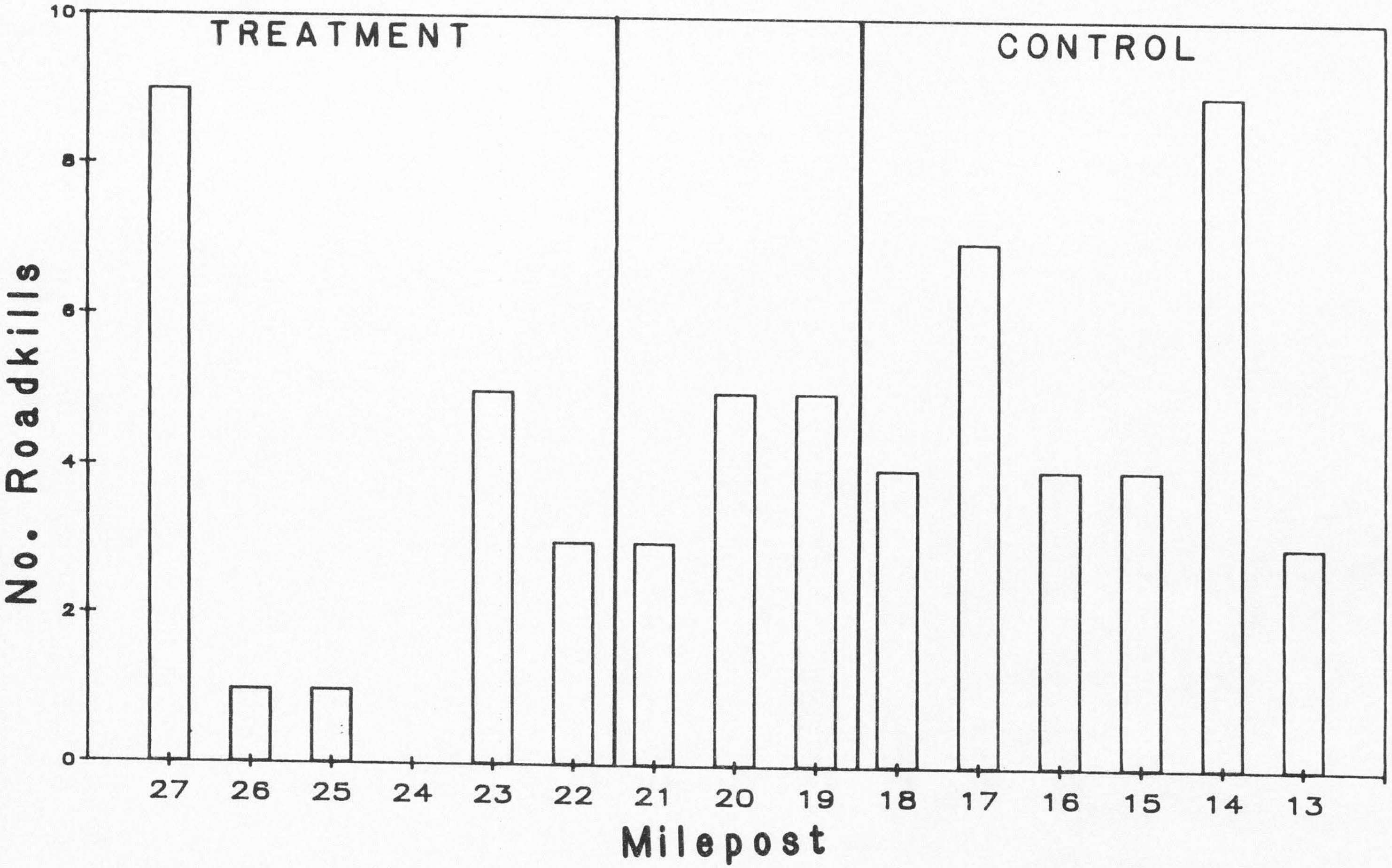

Figure 2. Roadkills occurring along Highway 28 (by mile) in 1985.

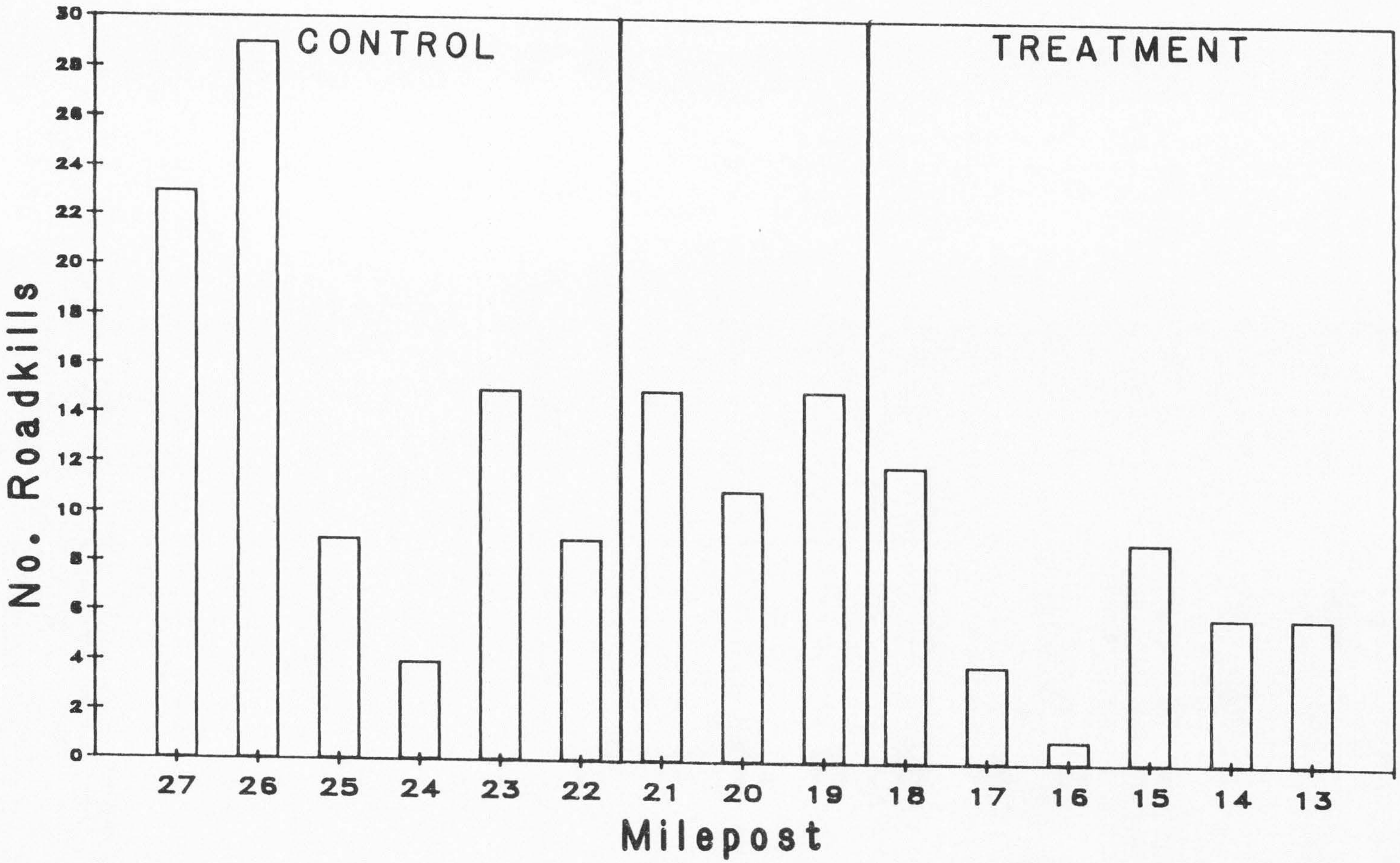

Figure 3. Roadkills occurring along Highway 28 (by mile) in 1986.

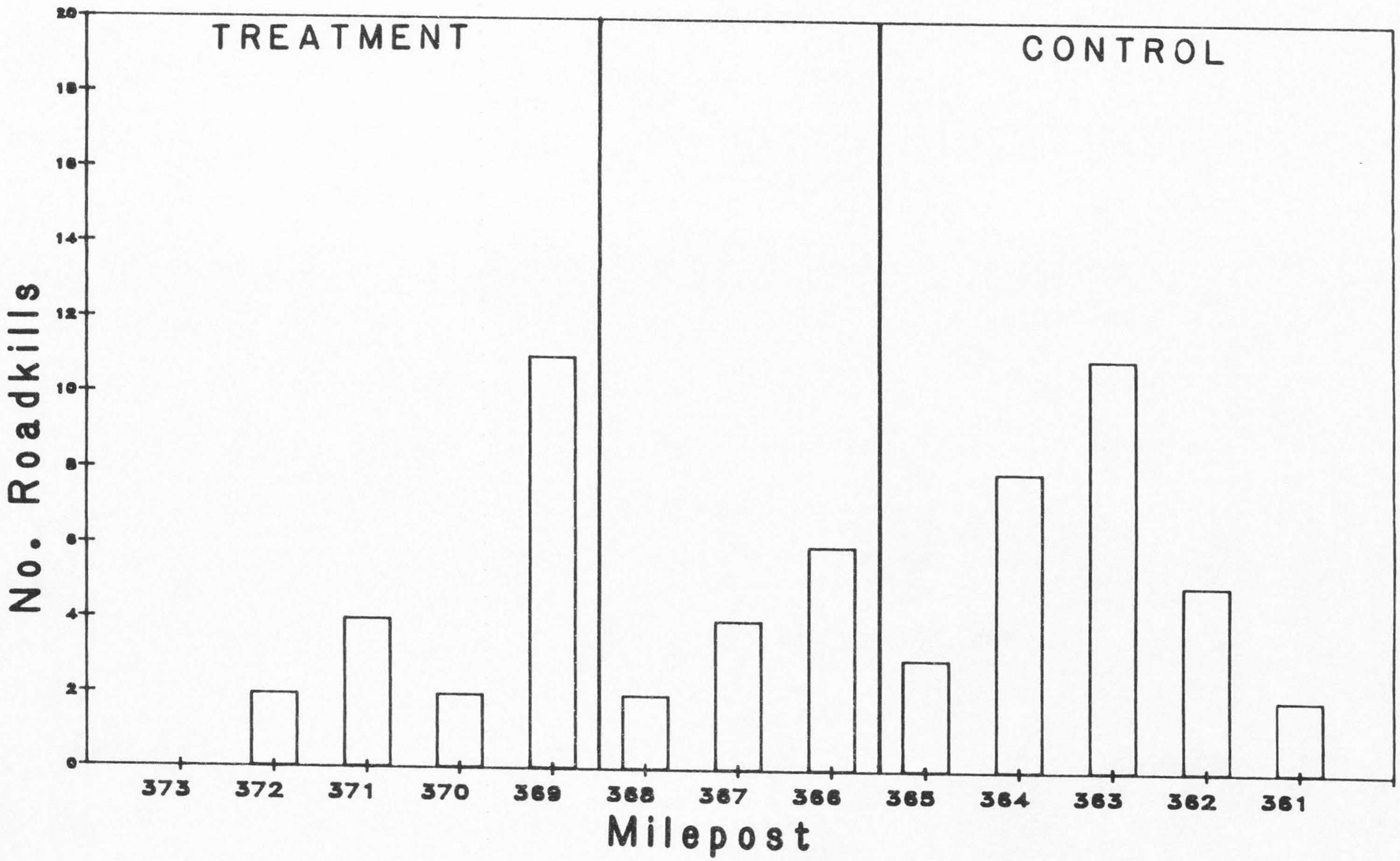

Figure 4. Roadkills occurring along Highway 89 (by mile) in 1985.

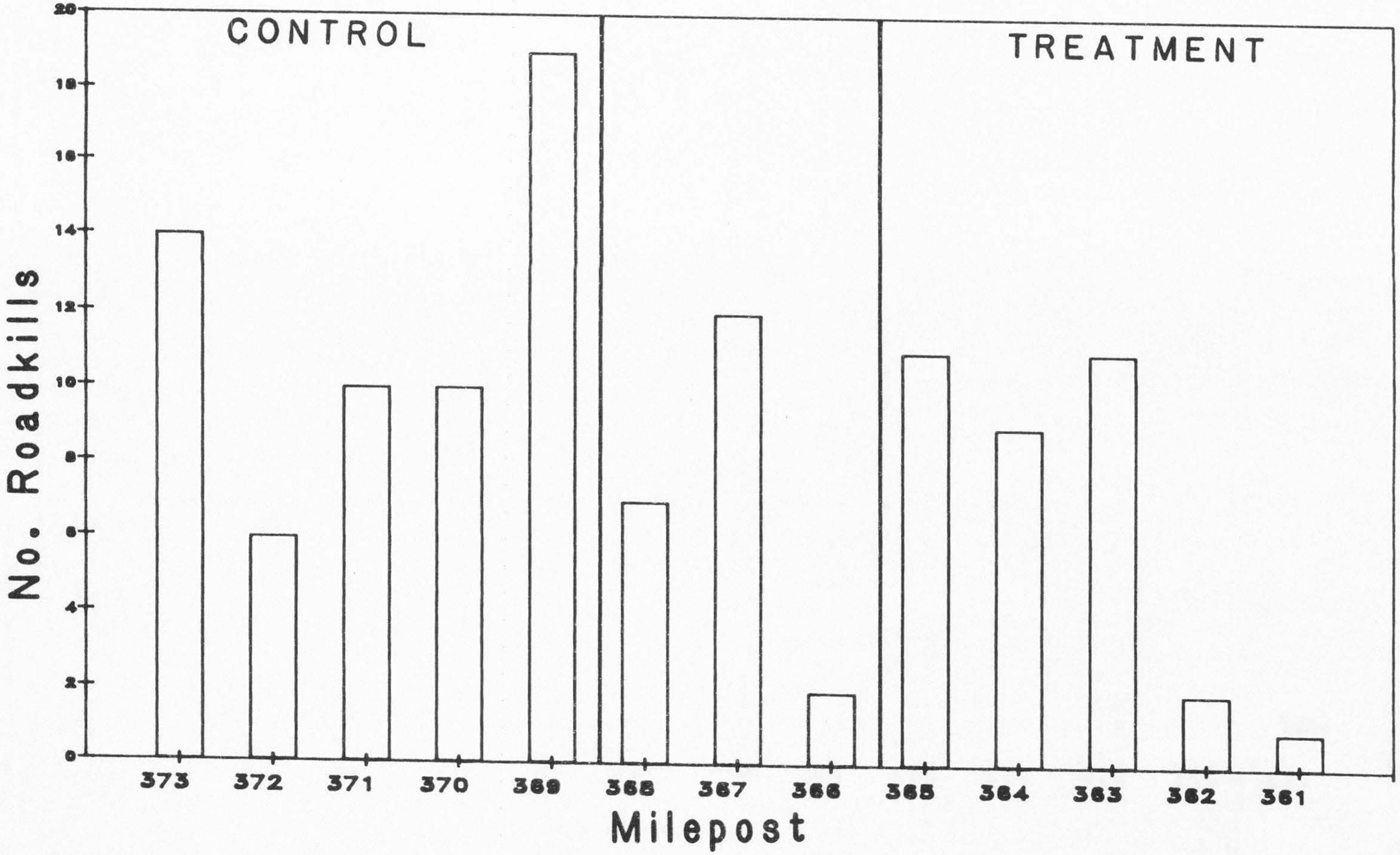

Figure 5. Roadkills occurring along Highway 89 (by mile) in 1986.

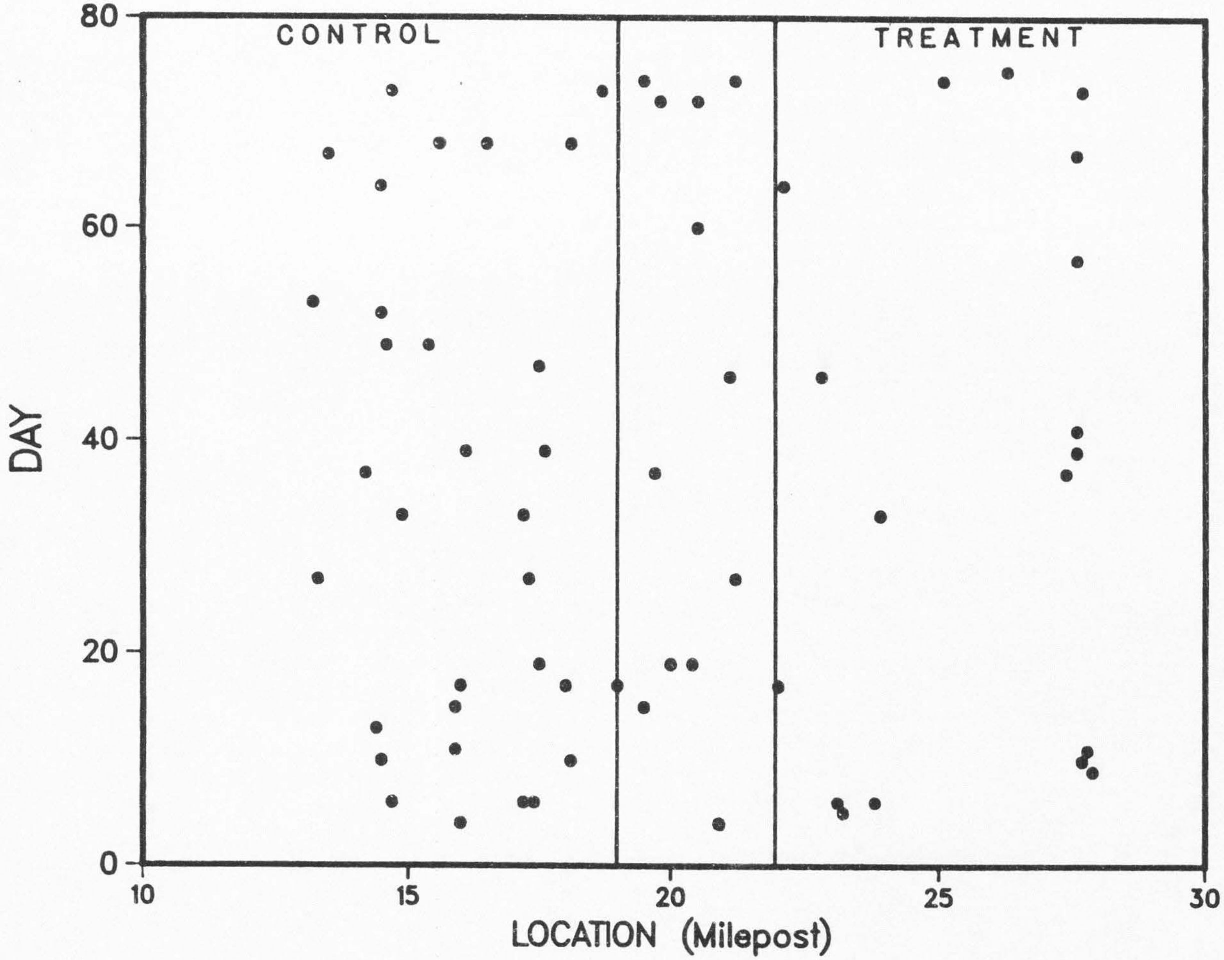

Figure 6. Temporal and spatial distribution of roadkills: Highway 28 in 1985.

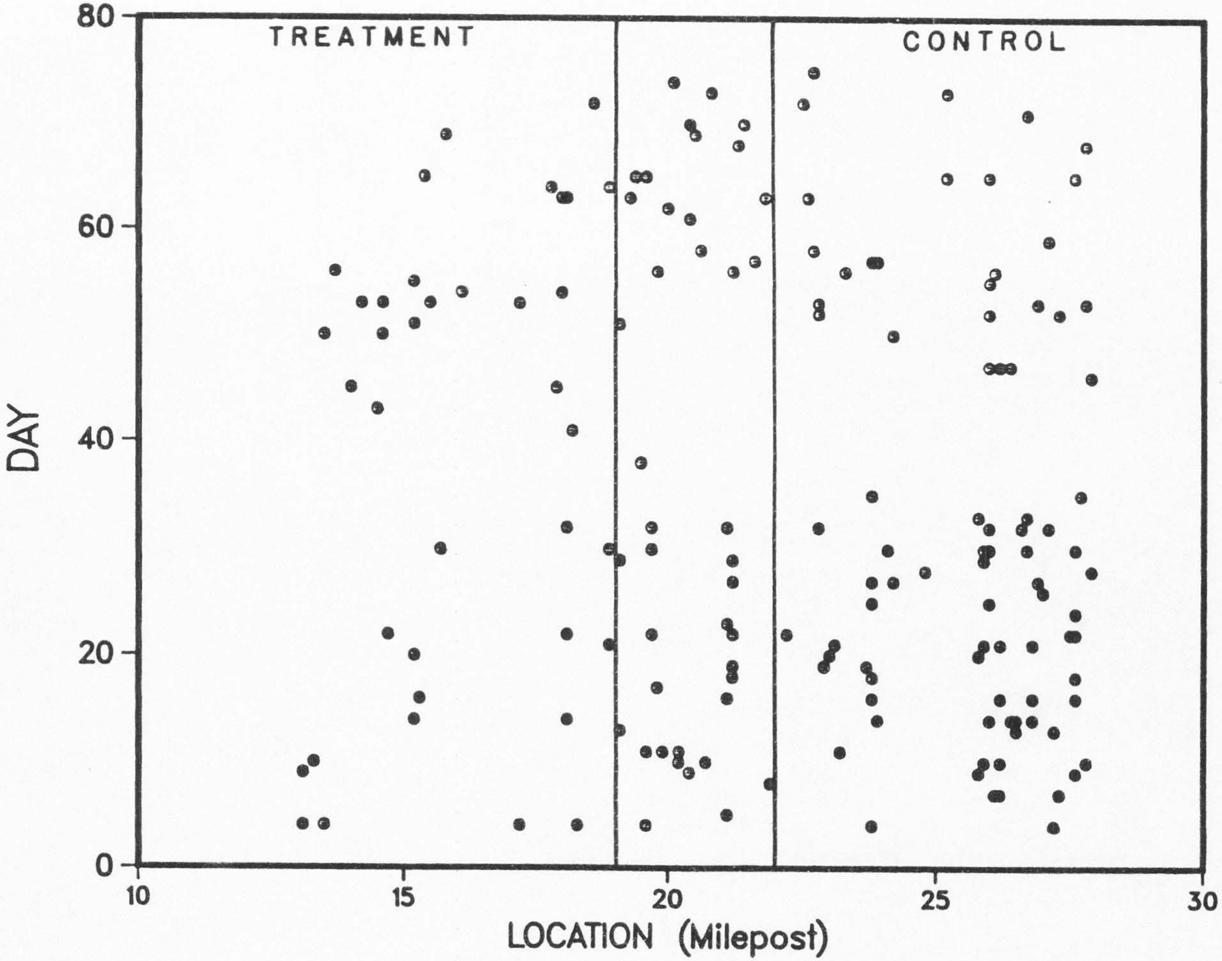

Figure 7. Temporal and spatial distribution of roadkills: Highway 28 in 1986.

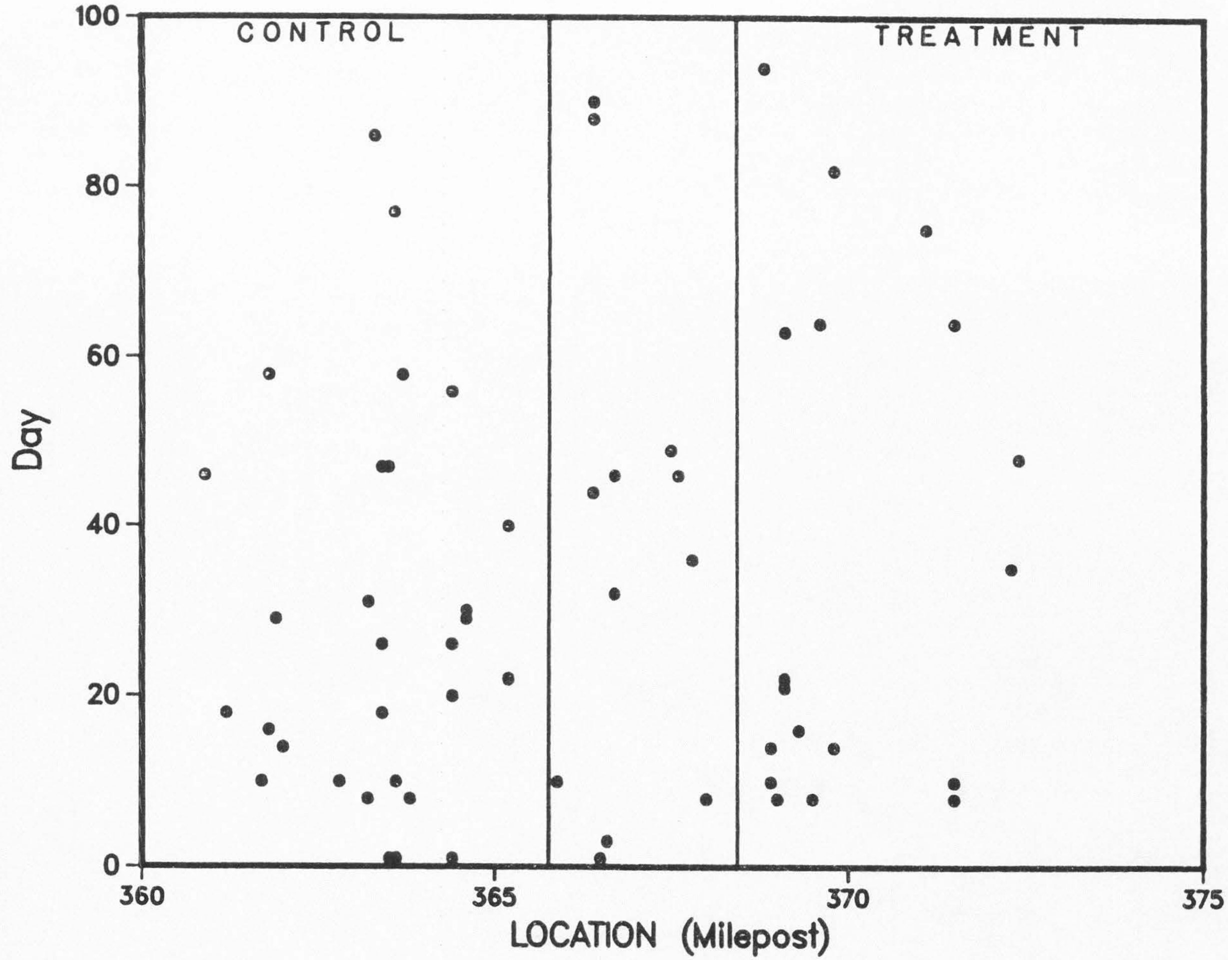

Figure 8. Temporal and spatial distribution of roadkills: Highway 89 in 1985.

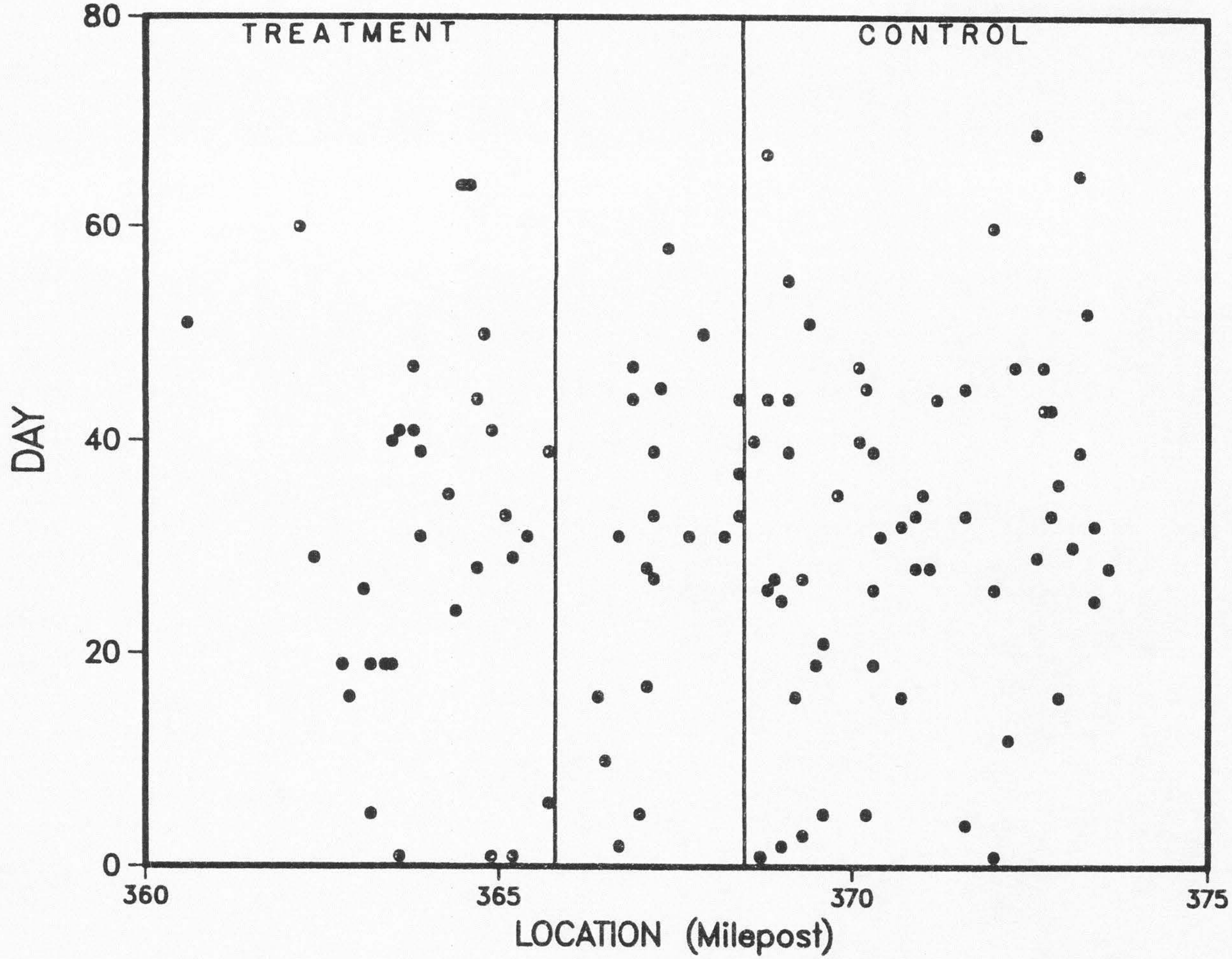

Figure 9. Temporal and spatial distribution of roadkills: Highway 89 in 1986.

Comparisons between the weather during January-March (NOAA 1985, 1986) in 1985 and 1986 provided insight into the temporal distribution of roadkills on Hwy. 28. In 1985, temperatures were consistently below average (by 2-3° C) and snowfall was substantially greater than that in 1986. For example, snowfall (cm) near Hwy. 28 for these 3 months in 1985 was 34.3, 35.6 and 42.7, respectively. Comparable figures for 1986 were 1.3, 15.5 and 5.1, respectively. Temperatures during 1986 were consistently above average (by 3-4° C) and were particularly anomalous in February and March, with temperatures often exceeding 15° C.

These weather conditions and their effect, direct and indirect, on deer movement patterns were reflected in temporal changes in the spatial distribution of roadkills on Rt. 28 in 1986. During the first 35 days (47%) of the study period, the weather was relatively average, and 100 (60%) of the roadkills occurred, with a ratio between control and treatment zones of 3.81:1. From the second week in February through the conclusion of the study period in mid-March, an exceptional increase in daily temperatures dramatically affected the distribution of roadkills. During the latter 40 days (53%) of the study period, 68 (40%) of the roadkills occurred with a ratio of 1.27:1 between control and treatment zones. Although the weather pattern in 1986 was similar on Hwy. 89, a similar phenomenon did not occur.

In 1986, herds began to withdraw from the foothills to higher elevations with the early onset of springtime conditions. Fewer deer used all feed sites and roadkill frequency decreased markedly during the last weeks of the study. Feeding was terminated 2 weeks earlier than in 1985 on Hwy. 89 and 1 week early on Hwys. 28 and 6.

Characteristics of the land adjacent to each highway influenced the spatial distribution of roadkills. Problem areas, where collision frequencies remained relatively high both years, were identified by tenth of a mile on Rts. 28 and 89. On Rt. 28 a problem area occurred between milepost 27.6 and 27.9, where visibility of deer around a bend in the highway was poor; and on Rt. 89, between mileposts 363.4 and 363.6, where deer circumvented a fenced orchard, crossing the highway at the north end of the fence.

The juxtaposition of Hwy. 6 in relation to deer movement patterns made it a special case. Deer moved parallel to the highway, along the natural travel lane afforded by the canyon. Deer were hit where they frequently fed alongside the highway. However, on some stretches, steep canyon walls precluded deer access to the highway.

More does were hit than bucks on Hwys. 28 and 89 both years (Table 2). Overall, the F:M sex ratio was 4.6:1. More fawns were hit than either yearlings or adults in 1985 on both highways, yet more adults were hit than fawns or yearlings in 1986 on both highways. Including all roadkills, the ratio of fawns:yearlings:adults was 1.9:1.0:1.8. There was no significant difference in the sex or age class ratios between the control and treatment zones of both highways during both years, suggesting that feeding did not select for sex or age classes.

Table 2. Sex and age classification of roadkills on Hwys. 28 and 89.

Highway	Sample size	Sex Ratio (F:M)	Age distribution Fawn	Yearling	Adult	Uncl.*
Utah 28						
1985	63	2.0:1	36	5	17	5
1986	168	4.3:1	63	27	65	13
US 89						
1985	60	9.0:1	22	17	15	6
1986	114	7.3:1	32	30	49	3

*Unclassified

Spotlighting

Fifty-one spotlighting surveys were conducted on Hwy. 28, 31 in 1985 and 20 in 1986. Significantly more deer were counted per mile in the control zone than in the treatment zone for all nights in 1985 ($P<0.001$), and in 1986 ($P<0.001$). In total, 47% more deer were counted in 1986 than in 1985 on the entire length of Hwy. 28. Deer counted per tenth of a mile on both east and west sides during both years are shown in Tables 3 and 4.

Tests of rank correlation between spotlighting counts and roadkill locations in 1985 revealed a stronger positive correlation between roadkill locations and total counts per

Table 3. Total number of deer spotlighted per tenth of a mile on Hwy. 28 in 1985.

	Milepost Marker	Nearest tenth of a mile: 0	1	2	3	4	5	6	7	8	9	Total
TREATMENT	27	109	77	65	159	68	25	60	68	96	163	890
	26	0	7	0	8	7	10	26	39	74	99	270
	25	0	0	1	0	17	0	0	1	0	0	19
	24	7	10	15	0	19	0	10	0	19	1	81
	23	20	78	53	12	2	10	0	18	65	26	284
	22	10	13	0	0	2	1	0	10	29	3	68
	21	112	134	137	108	8	0	2	0	5	5	511
	20	68	30	21	11	57	68	54	22	14	57	402
	19	226	29	61	61	35	46	101	113	84	28	784
CONTROL	18	46	76	66	32	100	36	23	83	104	41	607
	17	97	125	102	56	36	38	46	24	112	104	740
	16	45	25	61	30	84	125	143	102	69	59	743
	15	28	15	6	34	37	89	137	102	89	52	589
	14	248	49	11	44	65	29	163	29	15	43	696
	13	0	3	4	18	21	33	10	16	9	135	249

Table 4. Total number of deer spotlighted per tenth of a mile on Hwy. 28 in 1986.

	Milepost Marker	Nearest tenth of a mile 0	1	2	3	4	5	6	7	8	9	Total
	27	173	47	79	104	60	16	43	64	67	138	791
CONTROL	26	98	24	8	28	36	31	44	69	93	43	479
	25	46	0	11	44	8	112	106	170	121	57	675
	24	116	56	36	106	63	70	128	493	744	402	2214
	23	40	16	1	30	104	62	111	71	162	64	661
	22	25	22	89	32	23	2	12	61	49	62	377
	21	261	224	213	130	46	63	61	92	83	65	1238
	20	76	125	54	26	27	174	6	125	255	135	1003
	19	34	107	20	0	11	14	13	155	77	71	502
TREATMENT	18	57	85	137	126	89	26	29	121	66	13	749
	17	101	8	12	7	3	14	23	44	133	80	425
	16	1	8	16	16	84	16	38	21	54	131	385
	15	5	45	23	22	80	43	82	86	46	44	476
	14	46	17	15	8	17	7	24	7	13	12	166
	13	3	0	1	1	6	0	18	3	0	24	56

mile (r_s = 0.777; P = 0.002) than between roadkill locations and either west side counts per mile (r_s = 0.539; P = 0.022) or east side counts per mile (r_s = 0.694; P = 0.005). The data from 1986 also showed positive correlations between roadkill locations and total counts per mile (r_s = 0.411; P = 0.064) as well as with counts on the west side (r_s = 0.379; P = 0.078) and east side (r_s = 0.361; P = 0.089) of the highway (Figure 10).

Land features obstructed vision along 0.66 km (0.41 mi) of the northern 6 miles of Rt. 28 and 4.1 km (2.56 mi) of the southern 6 miles. Applying density estimates per mile corrected the direct counts by accounting for the locations and lengths of obstructions. The adjustments increased the estimates of deer counted in each mile where there were obstructions, but the pattern of deer distribution remained the same.

Browse utilization

Statistical testing revealed significant differences between browse utilization estimates on Hwys. 28 and 6 (p = 0.039), and between the treatment and control sites on these highways (P = 0.041). There was no significant difference (P = 0.064) between years and no browse utilization gradient indicating higher utilization closer to the site (P = 0.49). Deer or elk impacted the vegetation on and around the feed sites in varying degrees. Many plants on the sites were browsed more intensely than plants distant from the site, however the pattern of use

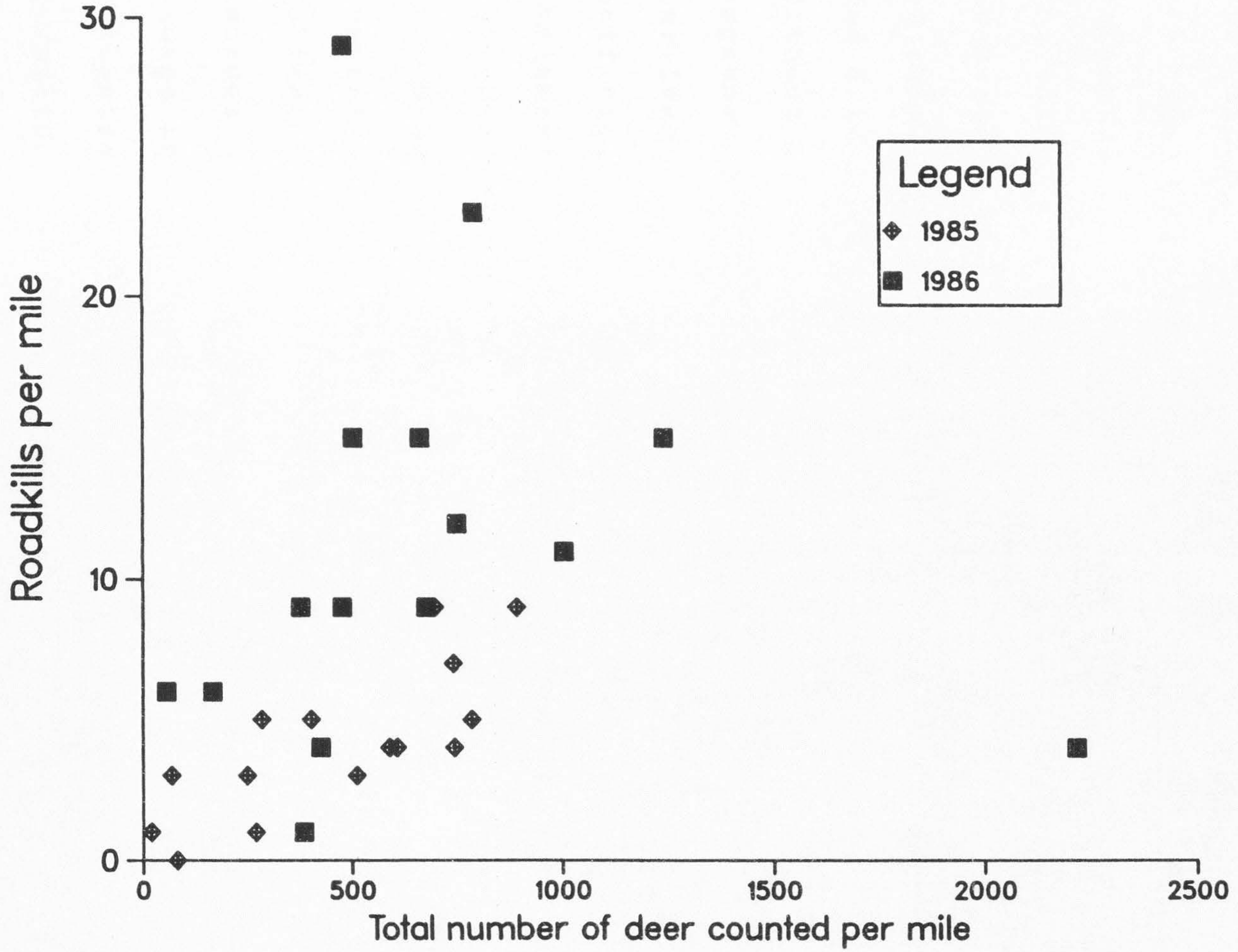

Figure 10. Number of roadkills per mile vs. total number of deer counted per mile on Hwy. 28.

was not consistent. The extent of impact varied depending on numbers of deer (or elk) using the site. On Hwy. 6, from 10 to 50 deer or 10 to 30 elk used each site; on Hwy. 28, from 50 to over 100 deer used each site.

Cost-benefit analysis

Costs of the project included foodstuffs, travel, and person-days of labor (Table 5). Pellets were donated, but the value of this donation was incorporated in the analysis. Depending on location, apple mash cost nothing or about $7/ton. Apple mash was not provided on Rts. 28 and 6 in 1986 because deer were attracted to the sites without it. Gas and truck mileage costs summarized the expenses of the 4WD pick-ups used for the project. Labor involved one full-time researcher on Rts. 28 and 6, and one half-time researcher on Rt. 89. The total cost for implementing intercept feeding on three highway segments for two years amounted to $18,355.

Damages resulting from deer-vehicle collisions represent the potential benefits realized when such collisions are prevented. I chose to include only two sources of potential savings, the average cost of vehicle damage and the value of a deer (Table 5), although I recognize the probability of benefits realized in other respects.

Allstate Insurance Company, which insures approximately 9% of Utah motorists, filed 242 animal/vehicle collision damage claims out of their

Table 5. **Costs of feeding on Hwys. 28, 6 and 89 and projected benefits described as damages forestalled.**

	Hay Cost($) (tons)	Pellets[a] Cost ($) (tons)	Apple Mash Cost[c] ($) (tons)	Gas & Mileage[e] $	Labor $	Total $	Cost per trt. mile $	Avg. No. Collisions per mile*	No. Prevented per mile**	Potential Benefits per mile ($)
1985										
Utah 28	2032 (26.8)	180 (1.0)	- (4)	1032	900	4144	691	1.09	2.00	1270
US 6	760 (10.0)	90 (0.5)	- (2)	840	450	2140	357	0.56	1.00	635
US 89	1598 (18.0)	270 (1.5)	107 (16)	1031	675	3681	708	1.11	1.92	1219
1986										
Utah 28	1492 (24.4)	180 (1.0)	- -	882	900	3454	576	0.91	8.50	5398
US 6	428 (7.0)	- -	- -	723	450	1601	267	0.42	-3.00	-
US 89	1280 (16.0)	700 (4.0)	250 (31)	430	675	3335	641	1.01	4.81	3054

	Avg. cost of vehicle damage ($)	Value of a deer ($)	Damages Incurred per Collision ($)
1985-1986	635	500	1135

[a]All pellets were donated by UDWR; cost estimates value of donation.
[c]Apple mash was donated on Hwys. 28 and 6.
[e]Estimated from miles driven.
*Average number of collisions per treatment mile equal to the average cost of vehicle damage divided into feeding costs per mile; i.e., the number of collisions requisite to equal feeding costs on a per mile basis.
**Number of collisions theoretically prevented per treatment mile.

Northwest regional office from January-March of 1986. Claims paid totalled $133,313, an average of $550 per accident. These claims were not exclusively deer-vehicle accidents, although the majority of them were (Allstate, pers. comm.). State Farm Insurance Company, which insures approximately 24% of Utah motorists, filed at least 90 deer-vehicle claims out of their Ogden, Utah, office from August 1985 through April 1986. Claims paid totalled $77,609; claims ranged from $91 to $2397, and averaged $862 per accident. The two averages yielded a weighted average of $635 per accident for vehicle damage.

On Hwys. 89 and 28, where feeding proved to be effective, there were 10 (53%) and 12 (63%) more roadkills in the control than in the treatment zones of the respective highways in 1985. In 1986, the differences were 25 (74%) and 51 (134%) more, respectively. Assuming the deer-vehicle collision frequencies for the highway segments were similar throughout their length, a total of 98 collisions were theoretically prevented in the treatment zones. Based on the average of $635 per collision, these 98 collisions potentially saved $62,230 in vehicle damage alone. This does not include human injury or fatality, property damages, or the value of a deer.

The Utah Division of Wildlife Resources (UDWR) set a maximum penalty charge of $1000 for the illegal taking of a deer. Consultation with UDWR indicated the most frequent charge assessed is $500. This quantity, summed with the average vehicle damage cost, provided an estimate for damages incurred per collision of $1,135.

DISCUSSION

Roadkills

The control vs. treatment ratio of roadkills suggested the efficacy of feeding. The results differed between years in two respects. First, the numbers of roadkill deer and deer spotlighted increased dramatically in 1986. Sufficient data are not available to determine if this was a function of population size. Weather influences on deer movement may have significantly affected the apparent deer population increase.

The second major difference was that the control vs. treatment ratio of roadkill deer supported the effectiveness of feeding more strongly the second year on Hwys. 28 and 89, whereas in the case of Hwy. 6, the ratio was reversed, and more roadkills occurred in the treatment zone.

Deer movement patterns along Hwy. 6 were parallel to the highway rather than perpendicular, as on Hwys. 28 and 89. Topography and difficult road conditions produced by snow and rain precluded transport of hay any further than 400 m from the highway at most sites. Deer movement to and from the sites frequently occurred along the highway. Moreover, on several sites, elk excluded deer from the hay.

The deer populations wintering along Hwys. 28 and 89, however, responded to the placement of feeding stations, or a variable which alternated similarly between years (correlation does not necessarily prove causality). In

1986, the unusual weather pattern demonstrated the potential for influence by weather conditions.

With premature springtime temperatures, green-up along the highways began earlier than normal. This change coincided with the significant reduction of the ratio of roadkills between control and treatment zones on Hwy. 28, reflecting the reduced effectiveness of the feeding sites. The attraction of young, green vegetation adjacent to the highway appeared to override the attraction of hay sufficiently to impact roadkill distribution. Development and orchards adjacent to most of the Hwy. 89 segment reduced the influence that early green-up had on roadkill spatial distribution. However, recalculation of the 1986 Benefit:Cost ratio for the first 35 days and for the latter 40 days on Hwy. 28 indicated the extent to which green-up influenced the efficacy of intercept feeding.

During the snow-cover period on Hwy. 28, 0.43 prevented collisions per mile (which would have incurred average damage) were requisite to equal feeding costs for that period, and 7.5 collisions per mile were theoretically prevented. During the green-up period, 0.48 prevented collisions per mile were requisite, and only 1 collision per mile was theoretically prevented. Roadkill frequency in the latter half of 1986 increased in the treatment zone relative to the control zone, although total frequency decreased. With this information, implementing intercept feeding would best be coordinated with the weather conditions most conducive to effectively attracting deer away from the highway.

Female deer were subject to a greater risk than males. This has been documented in other studies (Puglisi et al. 1974; Allen and McCullough 1976); although white-tailed deer exhibit seasonal changes in roadkill sex ratios more dramatically than mule deer. The highly skewed roadkill sex ratio of mule deer is likely a consequence of the skewed population sex ratio following annual deer hunts.

Spotlighting

Intuitively, deer counted on the west side of Hwy. 28 at night represented a higher risk to motorists because of their predictable highway crossing to return to bedding areas on the east side. However, counts on the west side showed a lower correlation with roadkill locations than total counts per mile in 1985 and 1986. This notwithstanding, the significant difference between deer counted in each zone demonstrated the effectiveness of intercept feeding. Nightlighting counts correlated sufficiently well with roadkills to offer potential for their use as an index to problem areas where deer-vehicle collisions are a high risk.

Roadkill or collision records would provide a direct index to roadkill frequencies, and therefore risk. When records are not available or are poorly representative of actual roadkill frequencies (as I have found with state records), nightlighting offers an alternative to identify stretches and very specific locations where deer movement patterns intersect highways.

Browse utilization

Sampling did not reflect the extent of impact deer using the feeding sites had on the surrounding vegetation even though analyses revealed statistical differences between the treatment and control sites. The impact included vegetation trampling and concentrated deposits of deer and elk feces. More intensive sampling of the area immediately surrounding the sites would more adequately describe the impact and its longer term effects on the vegetation.

The difference in browse utilization among years was not clearly significant. It appeared, however, that the impact of feeding the first year was not significantly carried over to the second year. Thus, it is possible that sites would recover without irreparable damage. One option to reduce big game damage to native vegetation proposed by Urness (1980) is to move feed sites periodically.

Cost-benefit analysis

Other studies (NSC 1980; Arthur 1981; Hansen 1983) have estimated the values of human injury or death and incorporated them into projected benefits yielded when accidents are prevented. Although these values are, in fact, realized when such damages are prevented, it is difficult to quantify values such as human life and injury

(Baram 1980). Objectivity will more likely prevail with an analysis of known values (or estimates thereof). The estimate of benefits will also be more conservative.

Although collisions almost invariably kill the deer, only a percentage of collisions result in significant vehicle, or other, damage costs. The analysis would be more conclusive if the percentage of vehicles involved in collisions causing average damage were known. Alternatively, I addressed a best estimate given by available information.

Comparable records from UDOT for collisions reported to police included only those for Hwy. 89 in 1985. According to these, 33 and 23 collisions occurred in the control and treatment zones, respectively, during the study period. This difference between zones (10) equalled the difference that I found, and the ratio of 1.43:1 was similar to my recorded roadkill ratio of 1.53:1. As discussed earlier, local officers confounded the roadkill counts; however, these records supported my assumption of uniformly distributed roadkill disappearences. UDOT records suggested that 100% of the roadkills were reported to the police; most of those reported caused significant damage (UDOT, pers. comm.). Whether, in fact, every roadkill from my records caused significant damage is uncertain.

Considering the cost of feeding ($18,355) and the average damage incurred by a collision ($1135), 16.2

collisions incurring average damage equalled the cost of feeding. Since the loss of the value of a deer does not involve a direct dollar transaction, the number of prevented collisions equal to feeding costs based on vehicle damage alone, increased to 29. Thus, if at least this many damage-causing collisions were forestalled, intercept feeding was cost-effective.

Recalling the likelihood of additional benefits accrued by preventing human injury or fatality (4-5% of deer-vehicle collisions cause injury; Arnold 1979; Hansen 1983), 29 is a conservatively high estimate. Feeding costs per mile on each highway averaged $213, yet varied per highway per year. The number of "prevented collisions" requisite for each highway each year to insure the cost-effectiveness of feeding depended on the feeding costs for each location per year (Table 5). On each highway for both years, with the exception of Hwy. 6 in 1986, the number of theoretically prevented collisions exceeded the number requisite to equal feeding costs.

At least 90 State Farm clients in Ogden, UT, filed claims for damage caused by deer-vehicle collisions between August 1985 and April 1986. Ogden comprises 7% of the population within the 4 most populated counties surrounding Salt Lake City (the latter comprising 77% of Utah's population; Rand McNally & Co. 1985). State Farm insures approximately 24% of Utah motorists. Assuming a similar deer-vehicle collision frequency for the remainder of the population in the Salt Lake Valley and for motorists insured by other insurance companies, the projected number of damage causing collisions for the 9 months between August of 1985 and April of 1986 was 5357.

UDWR (1986) recorded 2,430 roadkills for the state in fiscal year 1985. Clearly, these records are conservative. If UDWR's records represented less than half of the annual deer highway mortality, the projected number of damage causing collisions indicated that most, if not all, roadkills incurred damage. It is reasonable to suggest that where collisions involve primarily cars, as on Hwy. 89, most of the vehicles will sustain damage to some extent. Where collisions involve large trucks, as on Hwy. 28 where coal trucks cause about 50% of deer mortality, damage may not occur as frequently, but may be more costly when it does occur.

Sometimes overlooked are the actual numbers of deer lost due to highway mortality. In the continental states alone, hundreds of thousands are killed on highways; some areas are worse than others. Deer and other big game species represent a resource with not only ecological and aesthetic values, but also substantial recreational and, to an extent, nutritional values as hunted species. Agencies charged with the responsibility for wildlife management realize the potential for wildife conservation by addressing effective measures to reduce this wasteful cause of mortality.

If intercept feeding were applied operationally, some costs tallied in this study could be reduced. Labor, truck mileage, and gas costs comprised 49% of the total costs. These could be reduced by distributing the responsibility of feeding to cooperating individuals nearest each area where feeding was to be implemented. Foodstuffs purchased in large quantities would also be more economical.

Alternative techniques

As noted by Reed et al. (1982), high roadkill areas are best suited for fencing from an economic viewpoint because the benefit:cost ratio steadily increases with increased mortality prior to fencing. Their study demonstrated a minimum pre-fence mortality below which B:C ratios are unfavorable, even with 100% effectiveness. Installing 2.4 m deer-proof fencing along 7 Colorado Interstate highway segments cost on average $20,344 per mile, not including underpasses, overpasses or one-way gates. Allocating the initial capital for fencing foregoes investment opportunities, as well. Using a general equation for net annual return (see Workman 1986), the worth of $20,344 over a fence-life of 40 years can be calculated. Invested at 6% interest, the value of this initial capital is $1352/mi/year. Reed et al. (1982) recorded maintenance costs at 1% of the fencing cost, which would add $203/mi/year to annual costs. Installing underpasses, overpasses or one-way gates increases the cost considerably. Thus, investing in fencing is often prohibitively expensive.

The Swareflex reflector is innovative and has met with noteworthy success (Rudelstorfer and Schwab 1975; Gladfelter 1980; Williamson 1980; Schafer and Penland 1985). Developed in Austria, the designers assumed that red light flashes reflected by vehicle headlights were particularly effective in attracting a deer's attention (Gilbert 1982). Since white light from headlights is ineffective in preventing deer from crossing the road, the performance of the reflectors relies on deer responding to red light. A study of white-tailed deer color vision (Witzel et al. 1978) confirmed the functioning of both dark-adapted rods and color-sensitive cones in the eyes of deer. Both rods and cones were activated by longer (red) and shorter (blue) wavelength stimuli when light-adapted. However, cones did not respond to red flashes when dark-adapted. This weakens the arguement for the reflectors.

Whether it is the redness of the flashes created by a passing vehicle or simply a moving point source of light which produces the freezing response in deer, the reflectors are effective only during hours of darkness. Longer term testing will be necessary to determine whether deer habituate to the reflectors. Installing these reflectors on a straight roadway at the highest discounted price costs at least $775 per mile, not including installation (Strieter Corp. cost sheet). Minnesota and

Iowa Transportation Departments each paid at least $2,400 per mile to have reflectors installed (UDOT pers. comm.).

CONCLUSION

Significantly fewer deer-vehicle collisions occurred and fewer deer were counted within spotlighting distance of the highway segments where intercept feeding was implemented. The effectiveness of the feeding sites increased during 1986 on Hwys. 28 and 89, even with an increased number of deer killed and deer counted. The results from Hwy. 6 indicated the potential for intercept feeding to be less than cost-effective or ineffective. Given the variability between the three highways, Hwys. 28 and 89 were suitable for the cost-effective implementation of intercept feeding. On the other hand, Hwy. 6 provided valuable information on particular characteristics of a highway which are not conducive to effective intercept feeding.

The cost-benefit analysis indicated the minimum number of damage-causing collisions which needed to be prevented to justify feeding from an economic perspective, i.e. 29. Using damage claims paid in Ogden, UT, as a sample of the population of damage claims paid to insured motorists in the Salt Lake Valley for collisions involving deer, I demonstrated that most collisions involving deer incur some extent of damage.

UDOT's records for reported collisions, which typically entail some extent of damage, indicated a ratio of collisions between the control and treatment zones almost identical to the roadkills counted and a difference between zones that was identical to my records during the study period in 1985. A comparison for 1986 was not possible. In every case, except on Hwy. 6 in 1986, the benefits accrued by reducing collision frequency exceeded the costs of feeding. Particularly when large numbers of roadkills occurred in 1986, feeding on Hwys. 89 and 28 was over 4 and 8 times more effective, respectively, than necessary to pay for the costs of feeding.

Of the various methods used to reduce collision frequency, intercept feeding is not prohibitively expensive and desensitization is not a problem. Deer will always be attracted to a preferred food source, particularly a relatively "free" one such as supplemental food.

In conclusion, this project determined that intercept feeding can be an effective, although site-specific, technique to economically reduce the frequency of deer-vehicle collisions by diverting deer movement patterns away from a highway. It should be seriously considered in conjunction with the use of alternate techniques, in such a manner that the most appropriate technique is applied to each particular situation, to reduce collision risk to motorists and deer.

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